BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W.   WASHINGTON, D.C. 20024

B70 01019

SUBJECT: Behavior of Water vs Water Glycol for Control and Display Panel (Dry OWS) - Case 620

DATE: January 15, 1970

FROM: D. G. Miller

ABSTRACT

Relocating the ATM Control and Display (C&D) panel inside the MDA and using the AM suit coolant loop to cool the panel is baseline for the current AAP/SWS program. The C&D panel was formerly cooled by a water/glycol solution but the AM suit loop uses water as a coolant. Therefore, an analysis was conducted to compare the performance of water/glycol vs water as coolants. Results of this analysis indicate water to be the more effective coolant relative to heat transfer for this particular system. Also, water is shown to be more efficient from pump power and pressure drop requirements.

(NASA-CR-108817) BEHAVIOR OF WATER VERSUS WATER GLYCOL FOR CONTROL AND DISPLAY PANEL /DRY OWS/ (Bellcomm, Inc.) 11 p

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MEMORANDUM FOR FILE

Introduction

Current plans for the Saturn V Workshop place the ATM C&D panel inside the MDA. Since the C&D panel was formerly cooled by the LM which is no longer a part of the present assembly, another means of cooling the panel is required. It was recommended in Reference 1, and further considered at a meeting at MSFC on August 6 and 7, 1969 (Reference 2), to cool the C&D panel with water from the AM suit loop. Several factors in favor of the use of the AM suit loop are:

1. Presence of a Gemini ground control heat exchanger in the AM STS which can be plumbed into the AM coolant loop downstream of the STS cabin heat exchangers.

2. Simplicity of servicing the C&D panel from either suit coolant loop in the AM STS by means of appropriate flex lines.

3. Analysis indicates the AM suit coolant loop has the capability to handle the additional C&D heat load.

Figure 1 is a diagram of the proposed integration of the C&D panel with the AM coolant loop. As shown, a flex line is attached just upstream of the suit heat exchanger waterloop to the Gemini ground heat exchanger. Thereby coolant water is provided to the C&D panel in the MDA and is returned to the suit pump and reservoir by means of the other flex line shown in Figure 1. Since the C&D panel is presently designed for a water glycol solution, the effect of using water as a coolant will be analyzed.

In order to evaluate the performance of water relative to the water glycol mixture, a comparison was made between the coolant flow power requirement for water vs water/glycol to maintain essentially the same panel temperature. In this case a brief analysis was conducted using an idealized thermal/fluid model.

Present Thermal/Fluid Considerations

The C&D panel is designed for the following conditions pertinent to this analysis (Reference 3).

1. Input temperature = 53°F
2. Flow rate = 222 lb/hr (111 lb/hr in each of two tube passes)
3. Fluid = 35% glycol; 65% water (by weight)
4. Maximum pressure drop = 3.5 psi
5. All panel temperatures <105°F
6. Effective average panel temperature comfortable to crew.

The Airlock Module (AM) suit loop flows between 200-250 lb/hr water coolant in each of two loops. Since the suit coolant pump can deliver 222 lb/hr for the pressure drop encountered in the C&D panel, a comparison will be made between water and water/glycol at the same coolant flow rate and coolant heat gain.

An idealized fluid thermal model will be used wherein:

1. Assumed water/glycol and water system pumps have identical efficiencies.
2. Flow resistance loss assumed to be a function of flow length, i.e., no consideration to discharge coefficients or geometry loss.
3. For Reynold numbers ≤2000 the flow is isothermal, laminar, and Nusselt number = 4.4 (Reference 4).
4. For Reynold numbers >2100 the flow is in transition and approaching turbulent and McAdams pipe flow equation predicts the coolant heat transfer coefficient. (Reference 5)
5. AM coolant temperature (Coolanol 15) is 60°F. This is an estimated coolant temperature out of the STS heat exchangers which provide the cooling for the water suit loop as proposed in Reference 1.

6. Assumed coolant tubing effective heat transfer area = 1 ft^2.

7. Assumed Gemini ground cooling heat exchanger delivers water cooled to 61°F.

Results

It is estimated that use of water for cooling the C&D panel as compared with water/glycol can result in a power demand of 78% of the present requirement for water/glycol. The detailed difference in fluid/thermal performance is given below:

Coolant	Panel Coolant Inlet Temp °F	Panel Coolant Outlet Temp °F	Ave Coolant Wall Temp °F	Tubing ΔP lb/in^2	Flow Rate lb/Hr
Water	61.0	65.7	65.5	1.5	222
Water/Glycol	53.0	58.5	73.6	2.0	222

The average coolant wall temperature represents a good index of the performance of the coolant relative to the resultant panel temperature. From the data above it is seen that even though a higher coolant temperature is used for the water, the panel temperature will be several degrees cooler than in the case of the water/glycol coolant. The major reason for this difference is that the water coolant is in a transition flow regime whereas the water/glycol is essentially all laminar flow. This difference in flow regime results in the water having approximately an order of magnitude higher heat transfer coefficient than in the case of water/glycol. The effect of the change in the heat transfer coefficient is apparent from the basic equation for heat transfer to a surface.

$$q = hA\,\Delta T$$

where

q = Heat flux (BTU/hr)
h = Heat transfer coefficient (BTU/Ft^2Hr.°F)
A = Area (ft^2)
ΔT = Temperature difference between coolant and wall (°F)

Therefore, for the same heat flux transferred, the higher water heat transfer coefficient results in a smaller temperature difference between the wall and coolant and, in this case, gives a lower average wall temperature compared to water/glycol. From the heat transfer standpoint, water is the more effective coolant.

It should also be noted that the pump pressure drop and power required are significantly less for the water coolant. Therefore, from the standpoint of the lower power required, and the smaller pump pressure drop to accomplish essentially the same cooling, it appears the water is a more efficient coolant than the water/glycol.

Freezing Problem

The only apparent problem for using water in the C&D panel would be the possibility of the water freezing in the panel during storage. However, electrical heaters are provided on the walls of the AM to raise wall temperatures to a more tolerable level during storage and also prevent freezing of the water in the C&D panel.

Analysis

Ideally the power requirement for an incompressible fluid (coolant) can be expressed:

$$P = \dot{V} \Delta P$$

P = Power (lb-ft/sec)

$\dot{V}$ = Volumetric flow rate (ft^3/sec)

ΔP = Pump pressure drop (lb/ft^2)

or

$$P = \frac{\dot{w}}{\rho} \Delta P$$

where:

$\dot{w}$ = Flow rate (lb/sec)

ρ = Fluid density (lb/ft^3)

A simple comparison between two fluids can be made by dividing the individual power requirements to obtain:

$$\frac{P_1}{P_2} = \frac{\dot{w}_1 \; \rho_2 \; \Delta P_1}{\dot{w}_2 \; \rho_1 \; \Delta P_2}$$

Comparing the fluids at the same flow rate we obtain the following simple power ratio:

$$\frac{P_1}{P_2} = \frac{\rho_2 \; \Delta P_1}{\rho_1 \; \Delta P_2} \qquad (1)$$

The pressure drop for the two fluids occurs due to irreversible losses within the system, i.e., friction. It is assumed, for our case, that the total friction loss is mainly due to line friction which is expressed by the Fanning equation for isothermal flow in smooth tubes as:

$$\frac{\Delta P}{L} = \frac{2f \; \rho V^2}{gD}$$

f = Friction factor (dimensionless)

V = Line velocity (ft/sec)

D = Tube diameter (ft)

L = Tube length (ft)

The friction factor is strongly influenced by the flow regime which is a function of Reynolds number. For a diameter of 0.242 inches and a flow rate of 111 lb/hr the Reynolds number of the water/glycol is:

$$R_{e_{wg}} = 1{,}082 \text{ @ } 70°F$$

For the same conditions the Reynolds number of the water is:

$$R_{e_w} = 2{,}910 \text{ @ } 70°F$$

Based on a well established criterion of $R_e \leq 2000$ for laminar flow and $R_e \geq 4000$ for turbulent flow, it appears the water/glycol is laminar whereas the water is in transition.

Combining the equations expressing the friction factor with the Fanning equation we have for laminar flow:

$$\frac{\Delta P_{wg}}{L} = \frac{32}{g\rho_{wg}\, DR_{e_{wg}}} \left(\frac{\dot{w}}{A} \right)^2 \qquad \text{(Reference 4)} \qquad (2)$$

and for transition flow $R_e \sim 3{,}000$

$$\frac{\Delta P_w}{L} = \frac{0.1306}{g\rho_w\, DR_{e_w}^{\;0.228}} \left(\frac{\dot{w}}{A} \right)^2 \qquad \text{(Reference 5)} \qquad (3)$$

Substituting these equations into equation 1 gives:

$$\frac{P_{wg}}{P_w} = 245 \left(\frac{\rho_w}{\rho_{wg}} \right)^2 \frac{R_{e_w}^{\;0.228}}{R_{e_{wg}}} \qquad (4)$$

Equation 4 represents a simple mathematical model for estimating the power ratio of the water/glycol and water system. Dividing equation 2 by 3 we can estimate the pump pressure drop ratio as:

$$\frac{\Delta P_{wg}}{\Delta P_w} = 245 \; \frac{\rho_w}{\rho_{wg}} \; \frac{R_{e_w}^{\;0.228}}{R_{e_{wg}}} \qquad (5)$$

The effectiveness of the coolant is determined from an estimate of the average coolant tube wall temperature for the peak cooling load requirement. The equation describing the heat transferred from the wall to the coolant is:

$$q = h_L A \left(T_{w_{ave}} - T_{b_{ave}}\right) \tag{6}$$

where

q = Peak heat load (BTU/hr)

h_L = Coolant heat transfer coefficient (BTU/ft^2-hr-°F)

A = Effective heat transfer area (ft^2) (assumed 1 ft^2)

$T_{w_{ave}}$ = Ave. tube wall temperature (°F)

$T_{b_{ave}}$ = Ave. coolant bulk temperature (°F.)

The average coolant bulk temperature can be found from a simple energy balance as:

$$q = \dot{w}\, Cp\, \Delta T$$

$$T_{b_{ave}} = \frac{q + 2\,\dot{w}\, C_p T_i}{2\dot{w}\, C_p} \tag{7}$$

where:

$\dot{w}$ = Coolant flow rate (lb/hr)

C_p = Coolant specific heat (BTU/lb-°F)

q = Peak heat load (BTU/hr)

T_i = Entering coolant temperature (°F)

The heat transfer coefficient for fully developed laminar pipe flow in the case of the water/glycol is:

$$h_g = \frac{4.4K}{D} \qquad \text{(Reference 4)} \qquad (8)$$

where

K = Coolant thermal conductivity (BTU/ft hr °F)

D = Coolant tube inside diameter (ft)

For the case of transition pipe flow with a Prandtl number <10 McAdams' equation can be used, (Reference 5).

$$h_g = \frac{0.0225\ K\ R_e^{0.8}}{D} \left(\frac{C_p u}{K}\right)^{0.4} \qquad (9)$$

where

u = Coolant viscosity $\frac{lb - hr}{ft}$

$\frac{C_p u}{K}$ = Prandtl Number <10

Utilizing equations 6-9, the average coolant tube wall temperatures are calculated for the water/glycol and water. These tube wall temperatures approximate an average lower limit panel temperature, since thermal conduction from the electronic components would result in higher panel temperatures. The relative difference in tube wall temperature provides the basis for the coolant comparison on page 3.

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Attachments
References
Figure 1

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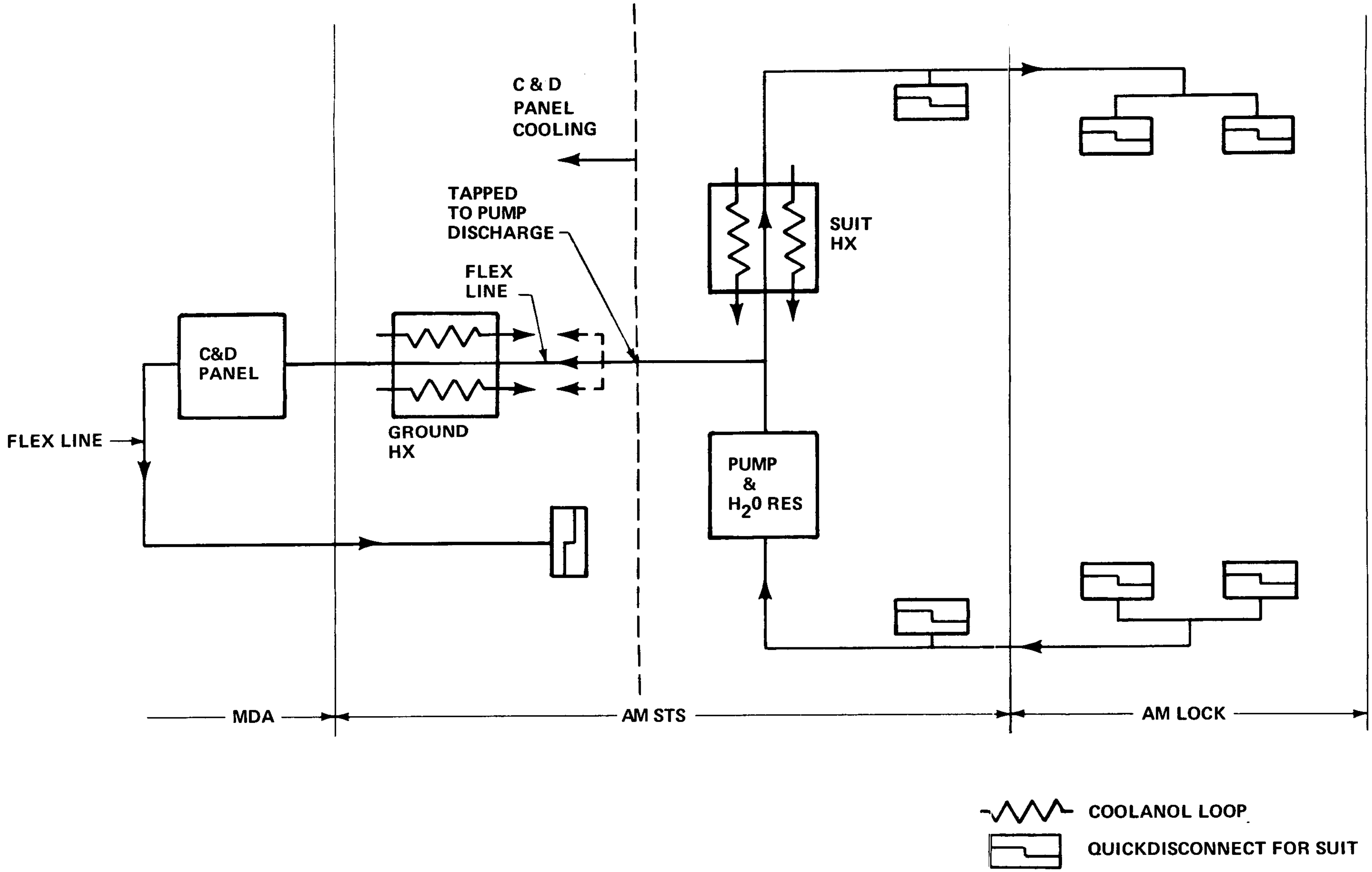

FIGURE 1 - INTEGRATION OF C&D PANEL WITH AM SUIT COOLING LOOP

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